Remote Sensing of Sea Ice Surface Thermal States in Polar Regions

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Changes in sea ice surface thermal states modify surface albedo, which induces further changes in surface heat balance and subsequent changes in ice surface temperature. An amplification effect in the ice-albedo feedback process has been recognized and various simulations of global warming have indicated the importance the ice-albedo feedback. In the feedback process, cloud cover interferes with the distribution of shortwave and longwave radiations, and thus strongly affects the surface energy balance. Yet it is currently uncertain whether the net cloud feedback is positive or negative because of the complexity of polar cloud feedback mechanisms in the atmosphere-ice-ocean system. To determine the overall effects, it is necessary to know sea ice thermal states under both cloud covered and cloud free conditions. The challenge is that traditional methods using radiometers such as AVHRR for surface temperature measurements fail under cloudy conditions.

Spaceborne imaging C-band radars such as the operational ERS and RADARSAT SARs or the future ENVISAT SAR has the capability to see through clouds and probe near-surface conditions of sea ice over large areas. The question is whether radar backscatter signature from sea ice is related or sensitive to surface thermal states. In this respect, we conducted controlled experiments to investigate the relationship between C-band radar signatures and sea ice thermal conditions. We obtained time-series measurements of sea ice backscatter, temperature, salinity, and other physical parameters over several diurnal thermal cycles. The experiments included two distinct thermal regimes for ice surface temperatures above and below the mirabilite ($Na_2SO_4 \cdot 10H_2O$) crystallization point. The results show that (1) backscatter is very sensitive (5-10 dB change) to ice surface temperature change, (2) the correlation between backscatter and temperature is positive, (3) the temperature cycling effects are reversible, and (4) the backscatter change is stronger over the higher temperature regime. The study indicates that the eutectic phase distribution and corresponding geometric variations of brine pockets are responsible for the observed backscatter signature of the thermal variations. From Arctic field data, an increase in ERS backscatter is observed with increasing ice surface temperature for first-year and younger ice but not for perennial ice. A sufficient amount of salinity in sea ice is necessary for observable thermal effects on backscatter. For Antarctic sea ice, this is particularly appropriate for remote sensing of sea ice thermal states because of the high salinity level compared to that contained in Arctic sea ice of similar age and structure. Combined with AVHRR imagery for cloud detections, radar signature from spaceborne SAR provides the basis to determine net effects of the cloud-ice-albedo feedback process.